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CBO PAPER

THE ECONOMIC EFFECTS OF FEDERAL SPENDING ON INFRASTRUCTURE AND OTHER INVESTMENTS

June 1998

CONGRESSIONAL BUDGET OFFICE
SECOND AND D STREETS, S.W.
WASHINGTON, D.C. 20515

NOTE

All years are fiscal years except where otherwise noted.

PREFACE

Growth in the productivity of the U.S. economy declined significantly after 1973, compared with the average rate between 1948 and 1973. Some observers argue that an increase in federal spending on infrastructure, education and training, and research and development (R&D) could lead to a significant increase in economic growth. As the near-term outlook for the federal budget improves and the Congress considers how to allocate expected surpluses among tax cuts, spending, and debt reduction, proposals for increases in those categories of federal spending have gained additional prominence.

This paper from the Congressional Budget Office (CBO), written in response to a request from the Senate Committee on the Budget, reviews the available data on the economic value of federal investments in infrastructure, education and training, and R&D. It focuses on empirical evidence produced since July 1991, when CBO last analyzed the issue in the study *How Federal Spending for Infrastructure and Other Public Investments Affects the Economy*.

Coordinated by Perry Beider, the paper was written by Nabeel Alsalam, Perry Beider, Kathy Gramp, and Philip Webre of CBO's Health and Human Resources, Natural Resources and Commerce, and Budget Analysis Divisions, under the supervision of Jan Paul Acton, Joseph Antos, and Bruce Vavrichek. Pam Greene prepared the box on tax preferences and Carl Muehlmann provided research assistance. The authors received valuable assistance and comments from E. Ross Crichton, Randall W. Eberts, John Fernald, David J. Forkenbrock, Harley Frazis, and Douglass B. Lee.

Melissa Burman edited the paper. Angela Z. McCollough prepared it for publication, and Laurie Brown prepared the electronic version for CBO's World Wide Web site (http:/www.cbo.gov/).

June E. O'Neill
Director

June 1998

CONTENTS

FIGURES

BOXES

INTRODUCTION AND SUMMARY

Over the long term, the rate of real economic growth (that is, adjusted for inflation) shapes the context of the choices that policymakers confront: the higher the growth rate is, the more the income that will be available to satisfy the needs and desires of the nation's citizens. For example, at the end of 30 years, the U.S. economy would have 45 percent more income if it grew at the 1948-1973 average rate of 3.9 percent per year as compared with the 1974-1997 average of 2.6 percent. Finding policies that encourage growth has proved difficult, however.

The key engine of long-term growth is growth in labor productivity—the output produced per hour of work. Labor productivity depends on the skills and knowledge workers have (human capital) and the materials and equipment available to them (physical capital). It also depends on less tangible factors such as technology, entrepreneurial talent, and the social and legal context in which firms operate. Accordingly, among the policies that promote economic growth are those that provide a hospitable environment for private investments in knowledge, equipment, and improved production processes.

All levels of government may also play a role in promoting growth through direct spending on certain categories of expenditures often classified as investments: public infrastructure (including roads, bridges, airports, transit, water supplies, and sewer systems), education and training (from preschool programs to elementary, secondary, and postsecondary education and on-the-job training), and research and development (R&D) in new science and technology. Federal spending on those categories of investment was $170 billion in 1997, accounting for 10 percent of total federal outlays—or about 2 percent of gross domestic product (GDP). Such federal spending is overshadowed by nonfederal spending in the same categories, however: in 1994 (the latest year for which comparable data are available), the federal total was $158 billion; similar spending by state and local governments and the private sector was more than $570 billion.[1]

Does the federal government spend enough on infrastructure, education and training, and R&D? Some observers contend that it invests too little in those areas and could boost overall economic growth by spending more. To assist the Congress in addressing that issue, this paper reviews evidence on the economic benefits of federal investment. It updates a more detailed Congressional Budget Office (CBO) study from July 1991, *How Federal Spending for Infrastructure and Other Public Investments Affects the Economy*.

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1. The latter figure includes spending by state and local governments for infrastructure ($126 billion), public primary and secondary educational institutions ($242 billion), and institutions of higher education ($47 billion), plus private-sector spending on research and development ($109 billion) and formal training ($50 billion, a 1995-1996 estimate). It does not include state and local governmental spending on private elementary and secondary schools, vocational postsecondary schools, financial aid to students and their families, or job training (all of which are relatively small). Nor does it include households' expenditures on education or the costs of informal on-the-job training.

This paper concludes that additional federal investment spending is unlikely to have a perceptible effect on economic growth. That result flows from the following observations:

- Many federal investment projects yield net economic benefits that are small, or even negative. Others yield high returns that would be forgone in the absence of federal involvement, but the number of such projects appears to be limited, and hence their potential impact on growth is small. Increases in federal investment spending that are not targeted toward cost-beneficial projects can reduce growth.

- Federal investment spending can displace investments by state and local governments and the private sector. Displacement is likely to be substantial in some cases, such as roads and bridges, which state and local governments have a strong incentive to fund because the benefits accrue primarily to local users. Federal spending that displaces other investment is unlikely to have a positive effect on growth.

- Many federal investments are motivated primarily by noneconomic policy goals (such as equality of opportunity, national security, and the advance of scientific knowledge). Others are influenced by political considerations. For those reasons, one cannot expect that federal funds will always be directed toward the most cost-beneficial use, even within those classes of projects that have an economic rationale.

The federal government could enhance the impact on growth of its current investment spending in two ways: by reallocating spending from low-return categories and projects to those with higher payoffs, and by adopting efficient pricing and management techniques in the use of existing capital.

AN OVERVIEW OF FEDERAL INVESTMENTS

In principle, the distinction between consumption and investment is clear: consumption yields immediate payoffs, while investment yields benefits over an extended period of time. In practice, many expenditures provide a mix of present and future benefits: college may be an enjoyable experience that also builds skills valued by future employers; an increase in law enforcement efforts may enhance people's sense of safety now and, by promoting business investment in productive activities and deterring people from becoming criminals, yield benefits in the future. The basic distinction remains, however: investments made today by individuals, businesses, voluntary organizations, and governments will help determine the nation's welfare in future years.

This paper focuses on those categories of federal investment that have the clearest connection to economic growth: infrastructure, education and training, and R&D.[2] By contrast, the government undertakes many investments (both within and beyond those three categories) partly or wholly to serve other social goals, and they should be judged in that light. Protecting endangered species and exploring the origins of the universe are examples of federal investments pursued largely for noneconomic reasons. And many public investments in human resources, even those in education and training, focus at least as much on increasing access (to health care, education, or job opportunities) as they do on economic benefits.

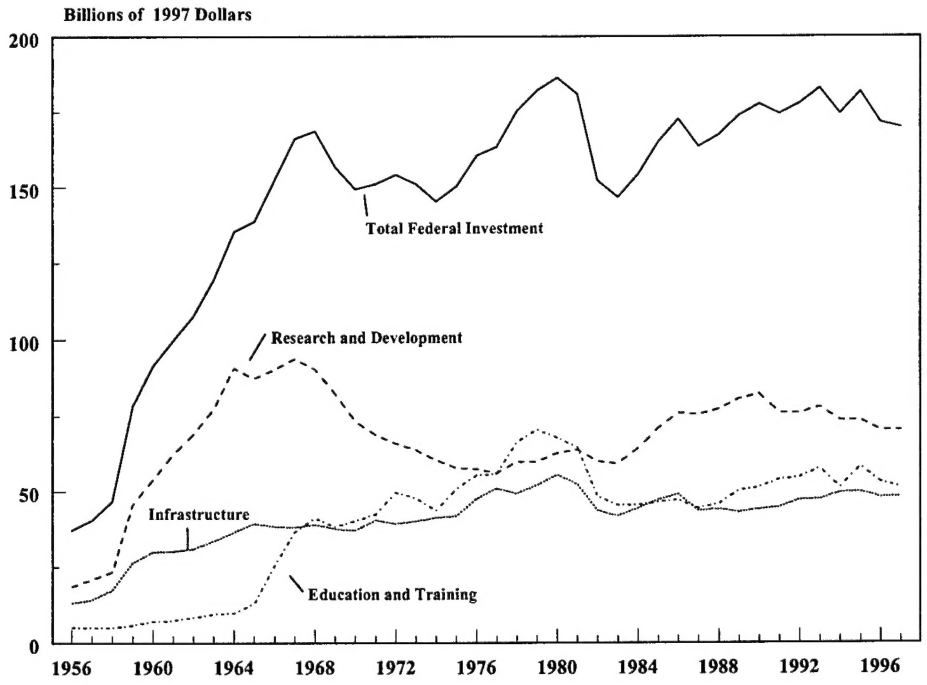
Some of the studies examined in this paper consider the effect of federal investment not only on measured output (GDP), but also on the broader concept of "economic welfare." The latter measure includes dollar values for unpriced goods and services based on estimates of what individuals would be willing to pay for them. The two concepts lead to similar evaluations of investment projects and programs in most cases, but not all. For example, a highway project could improve welfare (or be "economically efficient") without adding to GDP if a significant share of its benefit is in the form of increased leisure time for commuters; conversely, it could increase GDP but nonetheless reduce welfare if it leads to a significant increase in air pollution.

Trends in Federal and Nonfederal Investment Spending

In recent years, annual gross investment (that is, before subtracting the depreciation of past investments) by the federal government in infrastructure, education and training, and research and development has been close to its historic peak when measured in real, inflation-adjusted dollars; as a share of GDP or of all federal spending, however, it has declined significantly since the 1960s. Total investment more than quadrupled in real dollars between 1956 and 1968, as shown in Figure 1, thanks to initiatives such as the Interstate Highway System and the space program, and later the Great Society programs that began the federal government's involvement in supporting education for the poor. Real federal investment spending peaked in 1980, with increased funding for mass transit, rail, wastewater treatment, and various education and training programs. It dipped sharply thereafter, declining 20 percent by 1983, then rose fairly steadily through 1993. In proportional terms, federal investment has continued to decline relative to total federal outlays and GDP (see Figure 2). By 1996, investment spending had fallen to 10.7 percent of total outlays (roughly half of the 1966 peak of 19.9 percent) and 2.2 percent of GDP (down from 3.7 percent in 1967 and 3.4 percent in 1980). In itself, the relative

2. Other types of federal investments that could have been considered here are excluded because their connection to growth is indirect or secondary to their impact on other consumption and investment goals. For example, federal spending on health care is traditionally justified more on the basis of its impact on individuals' present and future quality of life than on its effect on worker productivity and economic growth.

FIGURE 1. REAL FEDERAL INVESTMENT BY CATEGORY, 1956-1997



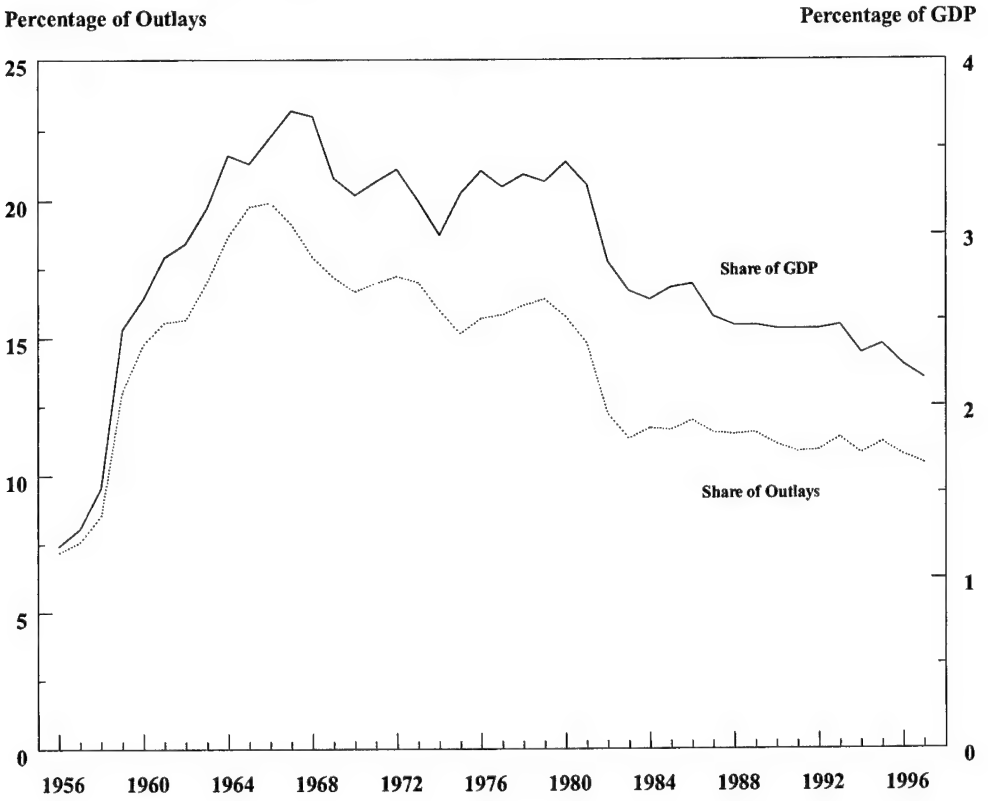
SOURCE: Congressional Budget Office.

decline is not evidence of underinvestment, since spending needs and priorities can shift as the economy grows and other circumstances change.

The federal spending shown in Figures 1 and 2 is only part of the total investment story: individuals, businesses, and state and local governments fund similar types of investments, and the private sector also invests in its own structures, equipment, and other physical capital. State and local governments now collectively spend three times as much as the federal government on infrastructure (see Figure 3). Similarly, private-sector spending on R&D, led by high-technology industries, is now twice the federal level, reversing the relationship that prevailed in the late 1950s and early 1960s (see Figure 4).[3] Complete historical data on spending on education and training are not readily available, but the federal component is clearly a small

3. For internal consistency, both the federal and private data on R&D spending are taken from a National Science Foundation (NSF) survey of institutions performing R&D. In contrast, the data on federal spending in Figure 1 are outlays reported by the federal agencies providing the funds. The two sources yield similar but not identical estimates of federal R&D. The reasons for the discrepancies, which appear to be concentrated in defense-related R&D performed by private industry, are the subject of study by the NSF.

FIGURE 2. FEDERAL INVESTMENTS AS SHARES OF GDP AND TOTAL FEDERAL OUTLAYS, 1956-1997

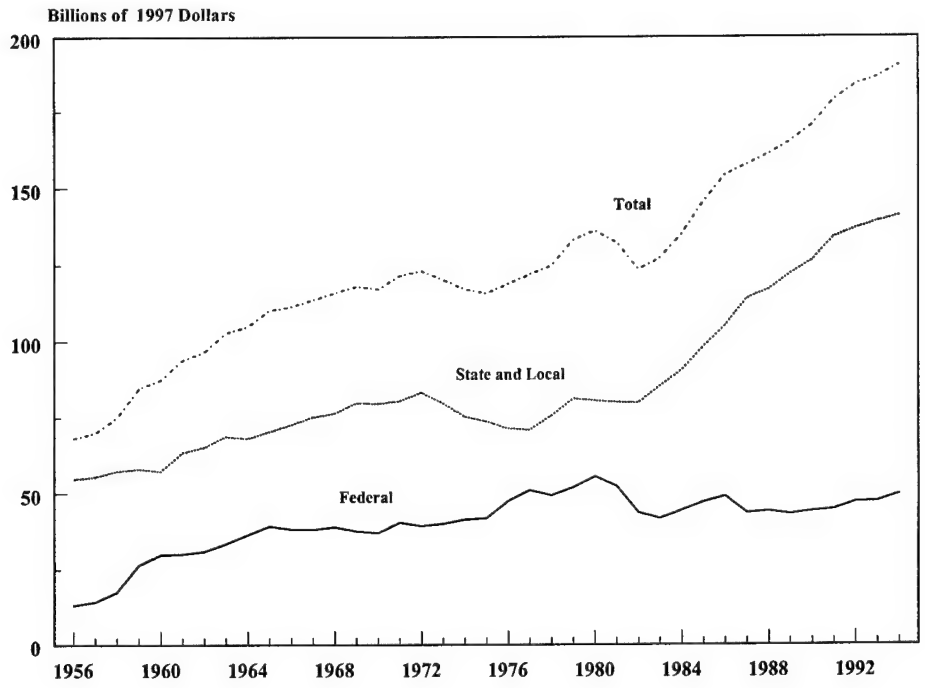


SOURCE: Congressional Budget Office.

share of the total; for example, federal support accounts for less than 10 percent of the revenue of educational institutions. When funding of infrastructure and educational institutions by state and local governments and private funding of R&D is added to the federal spending shown in Figure 2, the relative share of such investment in GDP is much more stable, falling slightly from 10.6 percent in 1970 to 10.0 percent in 1994.

A variety of federal tax preferences have encouraged investments by state and local governments and the private sector. Although those preferences do not represent federal outlays, they do affect the budget by reducing tax receipts (at least in the short run). Box 1 provides an overview of the federal tax preferences for the investments discussed in this paper.

FIGURE 3. REAL INFRASTRUCTURE INVESTMENT BY SOURCE, 1956-1994

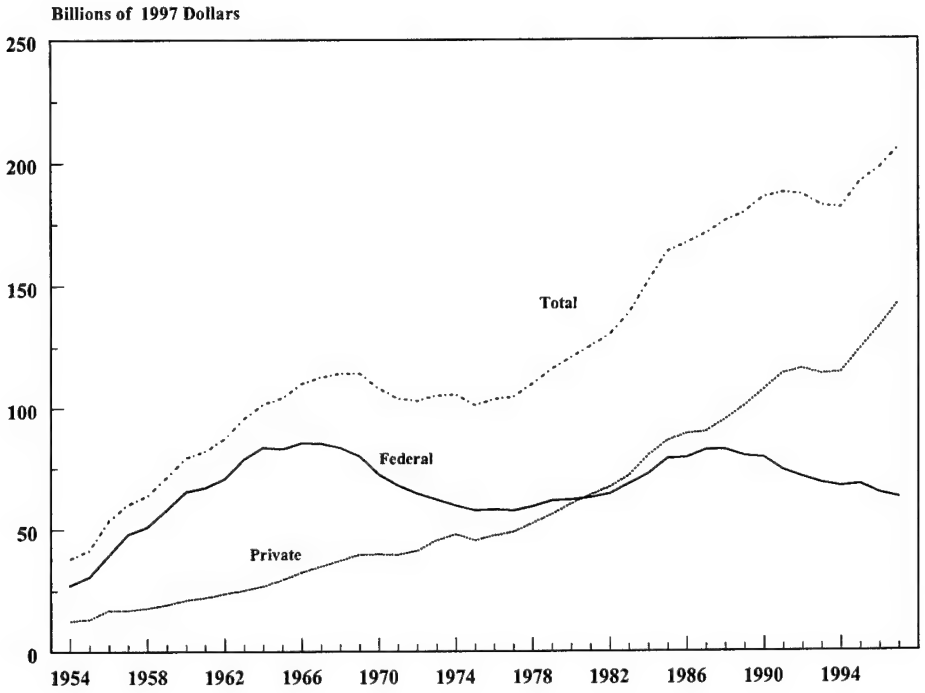


SOURCE: Congressional Budget Office.

Determining the Appropriate Level of Federal Investment

Given that state and local governments, businesses, and individuals fund many of the same categories of investments as the federal government, why is federal spending either necessary or appropriate? In some cases, federal investment is designed to promote equal opportunity or another noneconomic goal—for example, by standardizing the level of a good or service across the country or across various segments of society. On economic grounds, the federal government may have a unique role to play in correcting for specific factors that keep the private sector and state and local governments from providing efficient levels of certain goods and services. One example is investment in basic research. Private firms may invest less in such research than the socially efficient amount, particularly if the results are unlikely to be protected by patent, because some of the benefits of the resulting knowledge might "spill over" to other firms. Physical infrastructure may also yield some spillover benefits. For example, one rationale for federal support for highways is that some portion of the benefit provided by roads in one state accrues to residents

FIGURE 4. REAL RESEARCH AND DEVELOPMENT INVESTMENT BY SOURCE, 1954-1994



SOURCE: Congressional Budget Office based on data from National Science Foundation, *National Patterns of R&D Resources: 1997 Data Update*, November 1997 (available at http://www.nsf.gov/sbe/srs/natpat97/start.htm).

of other states.[4] Investment in education may have spillover effects to the extent that society reaps benefits (such as improved citizenship) beyond those received by individuals. Another rationale for federal involvement in education is to correct for the inability of some individuals who lack collateral to finance postsecondary education by borrowing in private markets.

4. That rationale assumes that state tolls and gasoline taxes paid by nonresidents do not adequately compensate states for the spillover benefits their roads provide. Traditionally, use of tolls has been limited by federal law and by the costs of collecting them—particularly the time cost to motorists of stopping and waiting to pay. New technology for electronic collection of tolls from vehicles traveling at highway speeds may make toll roads more attractive. See Congressional Budget Office, *High-Tech Highways: Intelligent Transportation Systems and Policy* (October 1995), pp. 32-34.

BOX 1.
TAX PREFERENCES FOR INFRASTRUCTURE, EDUCATION, AND RESEARCH AND DEVELOPMENT

Granting tax credits and exemptions to state and local governments, private individuals, and businesses is one way the federal government encourages investment in infrastructure, education, and research and development (R&D).[1]

In designing tax preferences, policymakers choose between broad and narrow investment classes and, within those classes, incremental investment—that is, investment above some previous level—and total investment. Preferences on narrowly defined classes give the federal government more influence over the investment choices of preference recipients and reduce the revenue cost to the Treasury, but they increase the risk of affecting those choices in unintended or inefficient ways. Incremental preferences cost less in revenue than nonincremental preferences, but the latter may be easier to administer or better serve other policy goals.

Infrastructure

Tax law encourages investment in public infrastructure by excluding interest on public-purpose state and local debt from the taxable income of bond purchasers, thus reducing the interest rate that state and local governments must pay to attract investors. The differential between taxable and nontaxable bond interest rates is effectively paid by the federal government through lower tax revenues, estimated at $16 billion in 1998.

The exemption covers bonds issued by state and local governments to finance capital facilities such as highways, schools, buildings, and parks. It also covers bonds for airports, docks, wharves, and high-speed intercity rail systems, even though current tax law defines such bonds as "private-purpose" (that is, benefiting private entities). Mass commuting facilities, such as bus depots and subway stations, and sewage, water, and hazardous waste facilities are also eligible for tax-exempt financing, subject to state-by-state volume limits specified in law. Revenue losses from private-purpose bonds accounted for another $2 billion in 1998.

Education

The major federal tax preferences that support investment in education include the following (with estimated revenue costs for 1998):

- The deductibility of charitable contributions to educational institutions ($3.5 billion);
- Personal exemptions claimed for dependent students ages 19 to 23 ($1.1 billion);

1. The tax code also includes a large number of provisions that serve as preferences for other types of private-sector investment. Some aspects of that broad topic are discussed in Congressional Budget Office, *Federal Financial Support of Business* (July 1995).

- The exclusion of interest on state and local bonds used to finance the construction of private, nonprofit educational institutions ($0.8 billion) and student loans ($0.3 billion); and
- The exclusion from income of employer-provided educational assistance ($0.2 billion).

The Taxpayer Relief Act of 1997 introduced additional tax incentives, at an estimated revenue cost of $3 billion in 1998 and $39.4 billion over five years. Those incentives include:

- A "HOPE" credit of up to $1,500 annually for the first two years of college, subject to certain taxpayer income phaseouts;
- A "Lifetime Learning" credit equal to 20 percent of the first $5,000 per year ($10,000 after 2002) of tuition for postsecondary education, subject to certain income phaseouts;
- A deduction for the cost of interest paid on student loans during the first five years of repayment, with specified limits and income phaseouts; and
- Education Individual Retirement Accounts (IRAs) designed to encourage taxpayers to save for postsecondary schooling.

The IRA rules allow up to $500 of after-tax income to be contributed annually for each beneficiary. Balances in the IRA accumulate tax-free and may be withdrawn tax-free, as long as the funds pay for the educational costs of students enrolled at least half time.

Research and Development

Two tax policy instruments serve to stimulate private R&D. A research and experimentation (R&E) tax credit has been available almost continuously since 1981, although its provisions have changed over time to reduce unintended disincentive effects. As currently implemented, the credit pays for 20 percent of the increase in a company's R&D spending above a historical base level; the exclusion of base-level spending is intended to avoid providing credits for R&D that would have occurred in any event. The dollar cost of the credit to the Treasury is small relative to the amount of federal R&D funding going to private industry: the Office of Technology Assessment reported that R&E tax credits claimed in 1992 represented 6.4 percent of federal R&D funds going to industry (or 2.6 percent of such funds to all recipients).[2] The Taxpayer Relief Act of 1997 extended the credit through June 30, 1998, at an estimated cost of $2.2 billion.

Additionally, since 1954, firms have been able to expense (that is, deduct immediately rather than depreciate over time) those R&D expenditures for which they did not take tax credits. In contrast to the credit, the expensing provision is not restricted to R&D activity in excess of some base level and defines R&D more broadly. That provision costs approximately $2.5 billion in revenues annually.

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2. Office of Technology Assessment, *The Effectiveness of Research and Experimentation Tax Credits* (September 1995).

Benefit-Cost Studies. The existence of a general economic rationale is no guarantee that a particular investment is worthwhile. To determine the economic worth of an existing or proposed investment, one must compare its benefits and costs. Benefit-cost studies estimate the dollar value of the effects over time from a particular investment project (or a relatively narrow class of projects) and summarize the effects in one of three ways.

- A "present value" is a weighted sum of a project's annual benefits net of costs, giving decreasing weight to effects that occur farther in the future. The weights are obtained by compounding an annual discount rate, which should be chosen to reflect the opportunity cost of forgoing investments elsewhere in the economy or of delaying consumer gratification.

- A "benefit-cost ratio" is the discounted sum (present value) of all present and future benefits of a project, divided by the discounted sum of all of its costs.

- An "internal rate of return" of a project is a rate that equates the present value of its benefits and costs.

All three summary measures usually give similar results. For some projects, however, more than one rate satisfies the equation for the internal rate of return. Consequently, benefit-cost analyses now typically report one of the other two measures, although rates of return are still widely cited as well.

Regardless of the summary yardstick, the proper measure of a project's cost is its "opportunity cost"—the gains forgone by not putting the invested funds to their most attractive alternative use. If an analysis of the project's present value or benefit-cost ratio includes and correctly measures all of the relevant benefits and opportunity costs, including the cost of delayed gratification reflected in the discount rate, then the test for economic efficiency is satisfied by a present value greater than zero or a benefit-cost ratio greater than one. Expressed in terms of rate of return, a project passes the test if it has a return that is not merely positive but greater than the discount rate. Identifying the appropriate discount rate and measuring other opportunity costs present conceptual and practical challenges, however (see Box 2).

An investment that is economically efficient yields an increase in GDP if its benefits and costs are reflected in the prices of marketed goods and services. Under that condition, the benefits and costs are the goods and services produced and forgone, and an efficient investment necessarily increases the total value of measured output. As noted above, however, the presence of unpriced goods or other nonmarket effects severs the connection between efficiency and output.

Statistical Studies. Benefit-cost studies can be described as "bottom-up" studies. In contrast, "top-down" studies use statistical methods to explore the relationship between the economy (or some sector of it) and one or more broad class of investment. Top-down studies model the relationship as either a "production function" (specifying the quantity of output obtained from given quantities of the relevant inputs) or a "cost function" (indicating the minimum cost of producing a certain level of output given prevailing input prices). Top-down studies analyze retrospective data, over time or cross-sectionally, to estimate the parameters of the production or cost function and derive implications such as the rate of return to particular inputs.

Top-down and bottom-up studies provide different perspectives on the economically desirable level of federal investment. Since top-down studies look at the big picture, they can offer guidance on broad questions of resource allocation and capture spillover effects that are hard to measure at the level of an individual project.[5] However, they focus entirely on aggregate economic effects and often lack sufficient data to accurately distinguish the impact of investment from the effects of other factors. Bottom-up studies can incorporate estimates of nonmarket effects (although assigning dollar values to them can be difficult), but their focus on individual investments or narrow investment classes limits their relevance for broad budget policy. Moreover, they often focus on the effects within some local area, thus failing to distinguish between economic activity that is new to the economy as a whole and activity merely shifted into the area from some previous location. Many bottom-up prospective studies may be particularly prone to erring on the side of optimism, underestimating actual project costs or overestimating benefits.

Because of the various limitations of top-down and bottom-up analyses, a single study of either type cannot be taken as definitive. Rather, one should draw conclusions on the basis of patterns found in many studies that use relevant data and rigorous methods of analysis.

FEDERAL INVESTMENTS IN PHYSICAL INFRASTRUCTURE

Physical infrastructure (or "public capital") refers to facilities and structures that are essential to the functioning of the economy; for present purposes, it comprises roads, bridges, rail and transit systems, airports, air traffic control systems, waterways, and water supply and wastewater treatment systems. Such infrastructure underpins economic activity by facilitating the movement of people and goods and by providing water and sanitation services essential to human health. Because it has

5. A few top-down studies helped bring the investment issue to prominence around 1989 by suggesting that a decrease in federal spending on infrastructure could explain much of the decline in GDP growth rates since about 1970, compared with growth rates seen in the 1950s and 1960s.

BOX 2.
MEASURING THE OPPORTUNITY COSTS OF FEDERAL INVESTMENTS

Analyses of the value of federal investments commonly confront difficulties measuring some of the relevant opportunity costs. One is the selection of a discount rate to represent the cost of delay between an initial investment and its subsequent benefits. Another is quantifying the opportunity cost of a dollar of tax revenues.

One way to select a discount rate for federal investments is to base it on returns to private investments. The Office of Management and Budget takes that approach, identifying its standard rate of 7 percent (in real dollars) as "the marginal pretax rate of return on an average investment in the private sector."[1] One important argument for the rate-of-return approach is that the most valuable alternative use of federal investment funds is generally private investment, not private consumption. Because capital income is taxed, private investors focus on projects expected to return enough not only to justify their delayed gratification but also to pay the required taxes. However, the feasible policy alternatives to a federal investment usually do not include any that yield a dollar-for-dollar increase in private investment, only various mixes of increased private investment and consumption. Thus, the rate-of-return approach provides an upper bound on the appropriate discount rate.

Two other discount rate approaches avoid the unrealistic assumption implicit in the rate-of-return method but have weaknesses of their own. One approach uses a weighted average of the private pretax rate of return and some estimate of the rate at which consumers are willing to exchange future benefits for current benefits. In general, however, a single weighted-average discount rate provides only an approximation of the true combined effects of the investment and consumption rates. Another approach, the "shadow-price-of-capital" method, is conceptually superior but highly sensitive to several factors (such as depreciation and reinvestment rates) that are uncertain in practice. Both the weighted-average and shadow-price-of-capital approaches face the additional difficulties of identifying consumers' rate of time preference and the distribution of the costs of a particular federal investment between private investment and consumption.[2]

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1. Office of Management and Budget, "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs," Circular A-94, revised (October 29, 1992), p. 9.

2. Consumer behavior varies significantly from the textbook model, with many individuals saving at one interest rate (or at multiple rates in different accounts) while simultaneously paying higher rates on credit card debt. Consequently, there is no single market in which "the" rate of time preference can be observed. Robert C. Lind, "Reassessing the Government's Discount Rate Policy in Light of New Theory and Data in a World Economy with a High Degree of Capital Mobility," *Journal of Environmental Economics and Management*, vol. 18 (1990), pp. S-19 to S-22.

some characteristics of a "natural monopoly"—in particular, high fixed costs that may inhibit private investors—it is generally provided by some level of government.

A fourth approach, generally used by the General Accounting Office in its analyses of federal investments, is to base the discount rate on the government's cost of borrowing.[3] The Congressional Budget Office has estimated the federal borrowing cost at roughly 2 percent per year in real dollars.[4] The borrowing-cost approach provides a lower bound on the appropriate discount rate; the more that changes in federal borrowing lead to changes in net exports and borrowing abroad, rather than changes in private domestic consumption or investment, the closer the bound.[5]

The problem of quantifying the opportunity cost of a dollar of tax revenue arises primarily because taxes distort relative prices and hence reduce the efficiency of economic activity (and to a lesser extent because of compliance costs). Thus, for projects that represent alternatives to tax cuts, each dollar invested may effectively cost the economy more than one dollar. Typical estimates of the opportunity cost of a dollar of tax revenue range from $1.20 to $1.60. Recent research indicates, however, that the magnitude of the distortion can vary significantly, depending on how the revenue is collected and spent.[6] Estimating an investment's effects on tax distortions can significantly increase the challenges of benefit-cost analysis.

3. General Accounting Office, Office of the Chief Economist, *Discount Rate Policy*, GAO/OCE-17.1.1 (May 1991).

4. Robert W. Hartman, One Thousand Points of Light Seeking a Number: A Case Study of CBO's Search for a Discount Rate Policy," *Journal of Environmental Economics and Management*, vol. 18 (1990), p. S-5.

5. Lind, "Reassessing the Government's Discount Rate Policy," p. S-12 to S-16. Even in the polar case of a fully open, small economy, the borrowing-cost approach may understate true social costs by neglecting the risks implicitly shifted to future taxpayers, rather than built into the interest rate, as with debt issued by a private firm.

6. See Charles L. Ballard and Don Fullerton, "Distortionary Taxes and the Provision of Public Goods," *Journal of Economic Perspectives*, vol. 6, no. 3 (Summer 1992), pp. 117-131. The authors construct examples in which the nature of the tax and the way the revenue is spent reduce distortions elsewhere in the economy and lead to an opportunity cost of less than $1.00 per dollar collected.

Trends in Federal Infrastructure Investment

Federal spending on infrastructure in 1997 was $48.3 billion, only about one-quarter of total spending on infrastructure by all levels of government. As in previous years, grants to state and local governments represented most of the federal dollars—$30.4 billion, or 63 percent. Of the 1996 stock of publicly owned infrastructure, 88 percent

was held by state and local governments, with just 12 percent owned by the federal government.[6]

Dividing federal spending on infrastructure into five categories—highways, mass transit and rail, water resources and transportation, aviation, and wastewater treatment—shows that the highways category is the largest of the five, accounting for 44 percent of the total in 1997 (see Figure 5). Real federal spending on highways rose rapidly following legislative authorization of the Interstate Highway System, reaching a peak in 1965 of $21.7 billion, measured in 1997 dollars. Thereafter, spending declined about one-third in real terms before rising again in 1982. In recent years, real highway spending has almost returned to its 1965 peak. Nearly all federal spending on highways comes out of the Highway Trust Fund (funded through the federal tax on gasoline and other excise taxes) and goes to the states in the form of grants. Those federal grant monies are combined with state and local funds, usually in 80/20 or 90/10 proportions. The federal share can be as high as 95 percent in states with large tracts of federally owned land, or 100 percent on projects classified as emergency relief.

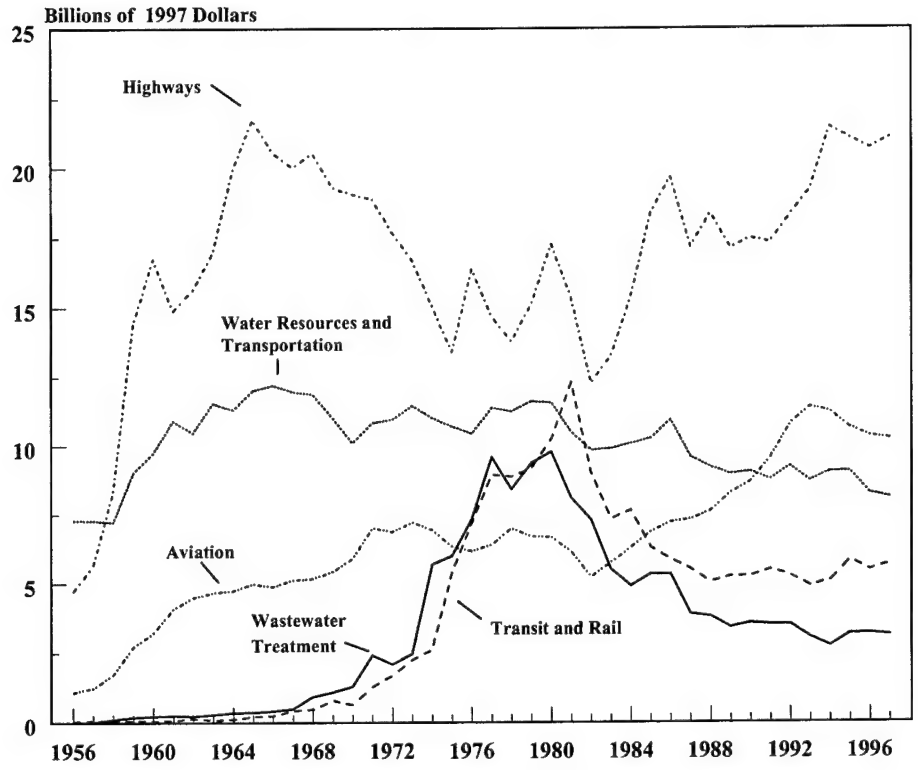
The water resources and transportation category represents spending by the Army Corps of Engineers, the Bureau of Reclamation, the Maritime Administration, and the Coast Guard for construction, operation, and maintenance of waterways (including locks and dredging operations), harbors, dams, and water distribution systems. Generally the second largest category from the 1960s through the 1980s, it reached its peak of real spending in 1966, at $12.2 billion in 1997 dollars, and has gradually declined since then, falling to $8.1 billion in 1997.

As federal spending on highways and water resources declined in real terms during the late 1960s and the 1970s, spending on mass transit, rail, and wastewater treatment rose, leading to the 1980 peak in overall infrastructure spending shown in Figure 1, above. In 1967, those categories accounted for $0.9 billion in 1997 dollars, just 2 percent of federal infrastructure spending; by 1981, the analogous figures had grown to $20.4 billion and 39 percent. Spending on wastewater treatment rose because the Congress appropriated grants to help local governments comply with the stricter standards in the 1972 Clean Water Act.[7] The bulge in transit and rail spending went to additional construction and operation of mass-transit bus and rail systems, Amtrak, and Conrail, which the government was readying for sale to the private sector. Such outlays fell quickly after peaking in the early 1980s: real transit and rail spending has fluctuated between about $5 billion and $6 billion each year

6. Based on the Bureau of Economic Analysis's data for "core infrastructure" and "conservation and development structures" (for example, dams).

7. The spending on wastewater treatment shown in the figure includes some small programs in the Departments of Agriculture and Housing and Urban Development that provide grants and loans for water supply systems.

FIGURE 5. REAL FEDERAL INFRASTRUCTURE SPENDING BY CATEGORY, 1956-1997



SOURCE: Congressional Budget Office.

since 1989, and real spending on wastewater treatment had fallen to $3.1 billion by 1997.

The only category of federal infrastructure spending other than highways to show significant growth during the 1980s is aviation. Sparked by strong growth in air travel, real spending on airports and air traffic systems almost doubled between 1980 and 1993, reaching $11.4 billion in 1997 dollars, then falling to $10.2 billion in 1997. Funds for aviation projects are appropriated from the Airport and Airway Trust Fund, financed by excise taxes on airline passenger tickets, international departures, cargo, and fuel used by general aviation, as well as from the general fund.

Returns to Investments in Physical Infrastructure

Both top-down statistical studies and bottom-up case studies examine the economic returns to federal investments in infrastructure. Both types have strengths and weaknesses, as noted above, and neither provides definitive estimates of the value of those investments. The results of most of the available studies suggest that the supply of projects with high economic returns is limited, and increases in infrastructure investment would not improve the rate of economic growth significantly, if at all. Moreover, an increase in federal spending on infrastructure need not yield a dollar-for-dollar increase in actual investment, because some portion of it would probably displace spending by state and local governments. Such displacement would reduce the net effect of the federal increase. Federal spending could even impede worthwhile investments, by encouraging states and localities to seek federal dollars and defer spending their own funds.

Top-Down Evidence. Since CBO's 1991 study, economists have published several review articles attempting to summarize and draw conclusions from the literature on the effects of physical infrastructure.[8] Some of the studies reviewed find that it has an insignificant or even negative economic effect, and a few others conclude that it has a large positive effect. A majority of studies suggest that public capital has a measurable but modest impact; however, limitations of the available data preclude any firm conclusion.

One study that brought the topic of infrastructure investment to prominence was published by David Aschauer in 1989.[9] Aschauer modeled a simple production function for the U.S. business sector from 1949 to 1985, using annual data on public capital, private capital, employment, and output. He found that an additional dollar invested in public capital yields a much higher economic payoff than another dollar of private capital. The conclusion derives from the high correlation between the time paths of productivity and the stock of public infrastructure: both grew much faster in the first half of the period (through about 1970) than in later years.

Many economists criticized that paper for relying on annual time-series data on national stocks and output. As discussed in CBO's 1991 study, the estimates resulting from that approach are highly sensitive to seemingly minor changes in the data—such as starting in 1950 rather than 1949, focusing on nonfarm business output

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8. See Congressional Budget Office, *How Federal Spending for Infrastructure and Other Public Investments Affects the Economy* (July 1991); Alicia H. Munnell, "Infrastructure Investment and Investment Growth," *Journal of Economic Perspectives*, vol. 6, no. 4 (Fall 1992), pp. 189-198; Edward M. Gramlich, "Infrastructure Investment: A Review Essay," *Journal of Economic Literature*, vol. 32, no. 3 (September 1994), pp. 1176-1196; Ronald C. Fisher, "The Effects of State and Local Public Services on Economic Development," *New England Economic Review* (March/April 1997), pp. 53-67; and Marlon G. Boarnet, "Highways and Economic Productivity: Interpreting Recent Evidence," *Journal of Planning Literature*, vol. 11, no. 4 (May 1997), pp. 476-486.

9. David Alan Aschauer, "Is Public Expenditure Productive?" *Journal of Monetary Economics*, vol. 23 (1989), pp. 177-200.

rather than all business output, or using a newer update of the same data.[10] Such sensitivity raises the question of whether the connection Aschauer found represents causality, some indirect linkage, or mere coincidence resulting from a small data set.[11]

Subsequent studies have used more sophisticated methods. One approach, "first-differencing," analyzes relationships between the period-to-period changes or growth rates of the chosen variables, rather than between their levels—the idea being that growth rates are less likely to drift together by coincidence. Another common approach examines cross-sectional or panel data for states, metropolitan areas, or industry groups, rather than national time-series data; analysts expect that the different experiences of the various smaller units of observation will yield a more robust set of data.

Studies that analyze data on first differences rather than levels of inputs and outputs do not support the findings of studies using national time-series data on levels. But first-difference studies have not yielded clear and convincing estimates of public capital's effect either. Alicia Munnell criticized early studies that used first-differencing for doing so without testing whether it was necessary. She argued that analyzing relationships between growth rates rather than levels may obscure long-run relationships, in part because the effect of an investment in one year may materialize over a span of several years.[12] Moreover, data in first-difference form may be more susceptible to measurement error. Two more recent studies—one each using national- and state-level data—applied statistical tests and concluded that first-differencing was indeed necessary. Like their predecessors, they yielded estimates that do not support Aschauer's thesis.[13] Both studies remain vulnerable to the criticism that they may have failed to identify lagged effects. Other studies have looked for such relationships by analyzing data observed at long intervals—for example, growth rates over a decade—but that approach greatly reduces the number of data points.

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10. For details, see CBO, *How Federal Spending for Public Investments Affects the Economy*, pp. 28-30.

11. One possible interpretation is that the data reflect a causal relationship running from greater national income to increased spending on infrastructure. At least one analyst has carried out some simple tests indicating that this interpretation fits the national data better than the opposite one. See John A. Tatom, "Paved with Good Intentions: The Mythical National Infrastructure Crisis," Policy Analysis No. 196 (Cato Institute, Washington, D.C., August 1993). Studies using industry- or state-level data, however, have found evidence that infrastructure can indeed lead to gains in productivity.

12. Munnell, "Infrastructure Investment and Economic Growth," p. 193.

13. Jan Egbert Sturm and Jakob de Haan, "Is Public Expenditure Really Productive? New Evidence for the USA and the Netherlands," *Economic Modeling*, vol. 12, no. 1 (January 1995), pp. 60-72; and Teresa Garcia-Mila, Therese J. McGuire, and Robert H. Porter, "The Effect of Public Capital in State-Level Production Functions Reconsidered," *Review of Economics and Statistics*, vol. 88, no. 1 (February 1996), pp. 177-180.

Even when they focus on levels rather than growth rates, studies that analyze cross-sectional or panel data on states, metropolitan areas, or industries have tended to produce smaller estimates of the impact of public capital than those using national time-series data. For example, a 1997 review article noted that eight of 15 studies on the state or local impact of highways found effects that are positive and statistically significant (reliably different from zero), while seven found either negative or insignificant effects.[14] Those results are consistent with the idea that the aggregate national-level results are spurious.[15] The estimated effects of public capital tend to be particularly low in subnational studies that include allowances for unobserved location- or industry-specific factors; again, it is possible that the allowances overcorrect for the influence of unobserved factors, obscuring some of the relationship between public capital and output.[16]

Comparatively few top-down studies of public capital have used the cost-function approach. One recent example, using annual state-level data from 1970 to 1987 to analyze the effects of highways and water and sewer systems on manufacturing costs, found dramatic savings. In 1982, for example, the marginal dollar of such infrastructure in the South saved manufacturers an estimated 31 cents per year in operating costs; in other regions, the analogous figures ranged from 16 cents to 18 cents.[17] Those high estimated benefits are surprising, especially because manufacturing represents only about 20 percent of the private economy and hence presumably captures only a fraction of the total benefit of public capital. Some of the resulting estimates of savings from manufacturers' own investments in private capital seem implausibly large, however—well above the cost of capital.[18]

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14. Fisher, "The Effects of State and Local Public Services," p. 54.

15. Spillover benefits across geographic boundaries do not seem large enough to account for the difference in results using national and subnational data. See, for example, Douglas Holtz-Eakin and Amy Ellen Schwartz, "Spatial Productivity Spillovers from Public Infrastructure: Evidence from State Highways," *International and Public Finance*, vol. 2, no. 3 (November 1994), pp. 459-468.

16. See the comments in Fisher, "The Effects of State and Local Public Services," p. 59; Gramlich, "Infrastructure Investment," pp. 1188-1189; and Boarnet, "Highways and Economic Productivity," pp. 479-480. Some studies use data from multiple countries; they face both the issue of unobserved country-specific factors and the additional problem that the data may be defined differently across countries. Perhaps as a result, the international studies have not yielded clear insights. Gramlich, "Infrastructure Investment," p. 1189; CBO, *How Federal Spending for Public Investment Affects the Economy*, p. 33.

17. Catherine J. Morrison and Amy Ellen Schwartz, "State Infrastructure and Productive Performance," *American Economic Review*, vol. 86, no. 5 (December 1996), pp. 1095-1111. The authors do not convert the annual savings, which vary from year to year, into a rate of return. In rough terms, however, one can approximate the rate of return by subtracting a geometric depreciation rate from the annual savings. If the benefits of infrastructure investments depreciate at 5 percent per year, for example, then the 1982 savings in the South of 31 cents on the dollar correspond to a 26 percent rate of return.

18. After adjusting for inflation in prices of capital goods between 1982 and 1987, gross savings from a marginal dollar of manufacturing capital in 1987 are estimated at 50 cents in the East and 60 cents in the North; net savings after borrowing costs, depreciation, and taxes are 15 cents and 26 cents, respectively. (The 1987 figures reported in the study are somewhat higher, representing nominal-dollar savings per unit of real capital, with the unit defined in 1982 prices.) Morrison and Schwartz, "State Infrastructure and Productive Performance," pp. 1095-1111.

Another cost-function study focused on highways and yielded rather different results. Commissioned by the Federal Highway Administration (FHWA), the study examined data from 1950 through 1989 on the savings provided by the highway system to the private economy, disaggregated into 35 industry groups, but did not attempt to measure the benefits for commuting and other personal travel.[19] It measured the highway system in two ways: the total highway stock (all federal, state, and local roads), and the "nonlocal highway system," which excludes investments by local governments. The study estimated that each dollar invested in the nonlocal network yielded about 24 cents annually in benefits to business, averaged over the period from 1950 to 1989; moreover, the average rate of return to such investments between 1980 and 1989 was 16 percent, compared with 11 percent for investments in private capital.[20] The study also reported, however, that the benefits were much higher in the early years, before the Interstate System was built, and diminished over time as the highway network expanded. By the 1980s, the overall stock of nonlocal highway capital was only 4 percent below the size beyond which further increases would cost more than they would return in benefits to business. Moreover, the total road network was yielding only 10 percent on additional investments, below the 11 percent return to private capital.[21]

Clearly, the econometric methods used in top-down studies of public infrastructure have grown more sophisticated since Aschauer brought the issue to wide attention. Those more refined studies have not produced solid evidence of positive returns to additional infrastructure investment. However, because the question is a difficult one and the available data are limited, the results remain inconclusive. Note that all the studies analyze the actual pattern of infrastructure spending; they do not consider the potential impact of shifting funds from low-return projects chosen for noneconomic reasons to projects with higher returns.

Bottom-Up Evidence. The available evidence from benefit-cost and rate-of-return studies sheds little light on the value of public infrastructure, for two reasons. First, different projects have widely different returns—from hugely profitable to net losses—so it is impossible to generalize from a handful of case studies. Analysts have produced few broad compilations of estimates covering large numbers of projects. Second, because bottom-up studies can differ in their scope and rigor (for example, prospective studies frequently err on the side of optimism), policy

19. M. Ishaq Nadiri and Theofanis P. Mamuneas, "Contribution of Highway Capital to Industry and National Productivity Growth," report submitted by Apogee Research, Inc., Bethesda, Md., to the Federal Highway Administration, Office of Policy Development, September 1996 (available on the FHWA World Wide Web site at http://www.fhwa.dot.gov/pubstats.html).

20. Those results are summarized in Department of Transportation, Federal Highway Administration, "Productivity and the Highway Network: A Look at the Benefits to Industry of the Highway Network," Publication No. FHWA-PL-96-016 (1996).

21. Nadiri and Mamuneas, "Contribution of Highway Capital," pp. 94-104.

conclusions should ideally rest on independent reviews that evaluate a set of studies from different sources. But again, few such independent reviews exist.[22]

The inherent difficulties encountered in drawing policy conclusions from bottom-up evidence are illustrated by benefit-cost data provided to CBO by the Federal Aviation Administration (FAA) and the FHWA. One obvious limitation of the FAA data is that they cover just 18 proposed airport improvement projects, analyzed by the agency between 1994 and 1997—too small a sample from which to judge airport investments as a class.

The FHWA data are more comprehensive: they provide prospective estimates of nationwide benefit-cost ratios for all improvements to existing highways that are expected to be efficient (that is, with a ratio of at least 1). However, the data are not derived from detailed analyses of thousands of individual projects but rather from a set of models—necessarily built on simplifying assumptions. The models estimate the benefits and costs of various types of paving, widening, and alignment projects, using data on some 123,000 segments covering roughly 30 percent of the highway network. They do so by applying formulas and tables that attempt to summarize key relationships, such as the influences of weather and truck traffic on pavement condition and of pavement condition on travel times and vehicle operating costs. The limited ability of the data to capture the specific circumstances of each of the modeled segments—for example, their connections to the rest of the highway network—limits the accuracy of the FHWA's analysis. Moreover, according to experts both within and outside the agency, the evidence for many of the relationships assumed in its models is sparse or obsolete.

CBO cites the two agencies' benefit-cost data here not as reliable evidence on the precise value of investments in airports and highways, let alone in infrastructure as a whole, but merely to illustrate some important qualitative points.[23] First, returns vary widely across investments, even within a particular category. Of the 18 airport

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22. On that point, see Gramlich, "Infrastructure Investment," pp. 1183-1184, and Massimo Florio, "The Economic Rate of Return of Infrastructures and Regional Policy in the European Union," *Annals of Public and Cooperative Economics*, vol. 68, no. 1 (March 1997), pp. 39-64. The latter compiles data from 200 benefit-cost studies submitted to the European Commission and cites analogous data from the World Bank, but those data have limited relevance for the United States.

23. Among the specific numerical findings that CBO does not consider compelling is an FHWA estimate that the total cost of efficient projects to maintain and upgrade existing highways is now $64.4 billion per year, measured in 1995 dollars. Actual 1995 spending by federal, state, and local governments on such projects was $29.2 billion.

The conclusion that efficient projects could absorb more than twice the current level of funding seems sharply at odds with the finding from the recent top-down study, discussed above, that the nonlocal highway system in the 1980s was only 4 percent below the size that would have maximized benefits to the business sector. One partial explanation for the contrasting results is that the benefit-cost data also incorporate the gains to individuals in commuting and personal travel. Another is that the top-down study adopted an estimate that each dollar invested costs the economy $1.46, based on an earlier study of tax-distortion costs—Dale W. Jorgenson and K.Y.Yun, "The Excess Burden of U.S. Taxation," *Journal of Accounting, Auditing and Finance*, vol. 6, no. 4 (Fall 1991)—whereas the benefit-cost data make no allowance for such distortion effects. Again, given the methodological difficulties faced by those studies, there should be no presumption that the findings from either one are correct.

projects analyzed by the FAA, for example, four had ratios below 1, indicating that their measured benefits would not justify their costs, while three had estimated benefit-cost ratios exceeding 10, including one with an astounding ratio of 105. There is no unique relationship that translates benefit-cost ratios into rates of return and vice versa, but a ratio of 10 probably corresponds to an annual return of 80 percent or better.[24] Of the remaining projects, four had ratios estimated between 1 and 2, five had ratios between 2 and 4, and two had ratios between 4 and 10.

Second, although some individual projects appear to have very high returns, they represent a small share of all investment opportunities. That point can be illustrated using data from the FHWA models on the universe of highway improvement projects expected to be efficient. When examined by project class and road type, the data show a very high average benefit-cost ratio of 12.1 for the set of efficient reconstruction projects on rural interstates, but that set includes relatively few projects, representing only 0.1 percent of total costs for all efficient projects.[25] In contrast, widening projects on all road types account for over 60 percent of all efficient investment dollars but yield a much lower average benefit-cost ratio of 1.8.

Third, the limited number of high-return projects suggests that increments to infrastructure spending would yield smaller benefits than those obtained from current spending. That would certainly be true under an investment strategy that funded the most valuable projects first, as can be illustrated using the FHWA's analysis. Based on an agency classification of 81 combinations of road type and project type, the 35 investment categories with the highest benefit-cost ratios have an average ratio of 5.89; funding the projects in those categories would cost just 30 percent of the total required for all efficient projects while yielding 70 percent of total net benefits (benefits minus costs). The other 46 categories have an average benefit-cost ratio of 1.87 and account for 70 percent of the costs but only 30 percent of the net benefits.

Fourth, the FHWA data support the idea that, beyond a certain point, maintenance and management of existing infrastructure become more attractive than investment in additional capacity, which tends to be more costly. Specifically, the estimates show that efficient resurfacing projects not involving shoulder improvements have a benefit-cost ratio of 6.0, averaged over all types of roads, compared with an average ratio of 3.2 for efficient projects that add new lanes.[26]

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24. The internal rate of return corresponding to a given benefit-cost ratio depends on the way the benefits and costs are distributed over time. If all of a project's costs occur up front and its benefits are spread evenly over 30 years, then a benefit-cost ratio of 10 implies an 80 percent return. Alternatively, the return is 94 percent if the benefits occur steadily over 20 years or 103 percent if the benefits occur over 30 years but decline 3 percent per year.

25. Data supplied to the Congressional Budget Office by staff of the Federal Highway Administration, December 2, 1997.

26. The remaining project categories and their average ratios are as follows: projects to improve road alignments without adding or widening lanes (a small portion of the universe of efficient projects), 6.2; resurfacing projects that involve shoulder improvements, 2.5; and lane-widening projects (a large set), 1.9.

Some experts carry the idea a step further, citing low-cost opportunities to make existing infrastructure more productive through efficient pricing and other management improvements; in some cases, such efforts may yield higher returns than more traditional investment projects—even those with attractive benefit-cost ratios. As CBO noted in a 1992 study, current taxes and fees do not closely reflect the costs users of the nation's airports and roadways impose on others through congestion and wear and tear.[27] Under rules designed to promote efficiency in infrastructure use, motorists and aircraft operators would pay fees (tolls or landing fees) based on their contribution to congestion of a particular facility at a particular time of day, and commercial truckers would pay taxes based on weight per axle (the key determinant of pavement damage). Clifford Winston and Barry Bosworth have estimated that efficient pricing of airport and road use would yield annual benefits of $22.2 billion in 1995 dollars. They also find that combining efficiency pricing with efficient investment—building highways with thicker pavement and adding runways at existing congested airports—would produce additional benefits of $12.7 billion per year, net of the incremental capital cost of $3.0 billion per year.[28]

The Displacement Issue. The top-down and bottom-up studies discussed above are studies of the value of infrastructure, independent of who pays for it. A thorough analysis of a particular federal infrastructure program must also consider the extent to which it actually increases total infrastructure investment rather than displacing spending by state or local governments.

Both theory and evidence suggest that significant displacement occurs. State and local governments have strong incentives to invest in infrastructure, even in the absence of federal assistance, since the majority of benefits accrue to local residents.[29] Moreover, some studies have found that state and local governments have delayed infrastructure investments in anticipation of subsequent federal funding.[30] Indeed, displacement seems to be a general phenomenon, not restricted to infrastructure: six studies out of nine cited in a review of the so-called "flypaper effect" found that grants from larger to smaller government jurisdictions reduced

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27. Congressional Budget Office, *Paying for Highways, Airways, and Waterways: How Can Users Be Charged?* May 1992.

28. Estimates from Clifford Winston and Barry Bosworth, "Public Infrastructure," in Henry J. Aaron and Charles L. Schultze, eds., *Setting Domestic Priorities: What Can Government Do?* (Washington, D.C.: Brookings Institution, 1992), p. 293, converted to 1995 dollars by CBO, using the GDP implicit price deflator.

29. Federal infrastructure spending may effectively increase the budgets of state and local governments and thereby make it easier for them to respond to the incentives for infrastructure investment. Federal matching grants available in limited amounts typically do not reduce the effective cost of such investment at the margin, however. In particular, most states exhaust their available highway grant money and fund additional projects for which they face the full construction cost.

30. See the citations in Gramlich, "Infrastructure Investment," p. 1991.

recipients' spending from other sources significantly—an estimated 35 cents to 75 cents per grant dollar.[31]

Summary. The available information suggests three conclusions: some investments in public infrastructure can be justified by their benefits to the economy, but their supply is limited; some (perhaps substantial) portion of federal spending on infrastructure displaces state and local spending; and on balance, the available studies do not support the claim that increases in federal infrastructure spending would increase economic growth.

FEDERAL INVESTMENTS IN EDUCATION AND TRAINING

The productivity of the nation's workforce is determined not only by the physical capital it has to work with but also by the skills and effort of the workers themselves. This section considers how much the nation as a whole and the federal government in particular have invested in education and training in recent years. It also reviews evidence on both the benefits and costs of specific types of education and training that the federal government funds.

The Size of Federal and Nonfederal Investments in Education and Training

The simplest available estimate of total private and public spending on formal education is the nation's aggregate expenditure by educational institutions—schools, colleges, and universities. In 1995-1996, educational institutions spent approximately $530 billion, nearly the same as businesses spent on durable equipment. That spending represented 7.3 percent of GDP, up from about 4.7 percent in 1959. Since 1969, spending by educational institutions has stabilized around 7 percent of GDP.[32]

Those figures exclude most formal and informal investments in on-the-job training. Formal on-the-job training typically involves trainees and an instructor meeting at a scheduled time and possibly in a special facility. In 1995-1996, firms spent approximately $50 billion (1.8 percent of payroll) on job-related training. Half

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31. James R. Hines Jr. and Richard H. Thaler, "Anomalies: The Flypaper Effect," *Journal of Economic Perspectives*, vol. 9, no. 4 (Fall 1995), p. 219. Grant providers in the nine studies include the federal and state governments; recipients include states, municipalities, and school districts. The phrase "flypaper effect" refers to evidence that intergovernmental grants "stick" to recipients' budgets more than they would if recipients treated them the same as increases in local income. The other three studies cited found essentially a dollar-for-dollar flypaper effect, implying no displacement at the level of recipients' overall budgets.

32. Those figures understate investment in education by neglecting opportunity costs, primarily in the form of students' forgone earnings. Opportunity costs can be a major component of the total cost of investing in the education of working-age students. The figures on annual spending in this subsection represent a mix of fiscal years ending in a given calendar year; public schools in most states operate on a July-June fiscal year, but a few states and some private educational institutions use other calendars.

of that was direct expenditures related to providing the training (including some spent at educational institutions) and half was the salaries of trainees. Informal training, which includes learning by doing as well as help provided by a coworker or supervisor, is hard to measure but may account for the bulk of on-the-job learning.

In 1997, the federal government spent approximately $53 billion, or about 0.7 percent of GDP, on education, training, employment, and social services.[33] That percentage increased from less than 0.2 percent of GDP in 1959 to nearly 0.9 percent in 1968, then fell to roughly 0.7 percent in the mid-1980s. The figures exclude expenditures to train the government's military and civilian employees; the Defense Department alone spent $3.2 billion for that purpose in 1997.

As a share of total national spending for education and training, federal spending is small but not insignificant. In 1995-1996, for example, federal dollars funded 8.8 percent of expenditures at educational institutions. The relative federal contribution was lower in elementary and secondary education (6.5 percent) than in postsecondary education (12.3 percent). Most federal spending is directed toward children with special needs and schools serving a high proportion of poor children.

Top-Down Evidence

Evidence from top-down statistical studies suggests that increases in the educational attainment of the workforce over the past few decades accounted for a modest but significant part of the growth in output per worker. The National Center for Education Statistics reviewed studies by Edward Denison and others and estimated that increases in educational attainment were responsible for 11 percent to 20 percent of the increase in worker productivity in recent decades.[34] Dale Jorgenson and Barbara Fraumeni estimated that growth in labor quality contributed 9 percent of growth in output per hour of work in the noneducation sector from 1948 through 1986.[35] The Bureau of Labor Statistics estimated that better education of the workforce accounted for 14 percent of growth in output per hour of work in the private business sector from 1948 through 1990.[36]

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33. *Budget of the United States Government, Fiscal Year 1999: Historical Tables*, Table 3.1.

34. Department of Education, National Center for Education Statistics, *Education and the Economy: An Indicators Report*, NCES 97-269 (prepared by Paul T. Decker, Jennifer King Rice, and Mary T. Moore, April 1997), p. ix.

35. Dale W. Jorgenson and Barbara M. Fraumeni, "Education and Productivity Growth in a Market Economy," *Atlantic Economic Journal* (June 1993), p. 16. Between 1979 and 1986, labor quality accounted for 14 percent of economic growth.

36. Bureau of Labor Statistics, *Labor Composition and U.S. Productivity Growth, 1948-90*, Bulletin 2426 (December 1993). Between 1948 and 1990, labor hours grew 1.0 percent per year, and labor input (hours weighted by workers' wages) grew 1.3 percent per year. The difference, 0.3 percent per year, is the growth in labor input caused by growth in the education and experience levels of the workforce. Note that workforce skill is not observed directly in those studies but inferred from wage rates. In particular, improvements in labor quality are

Although such studies suggest that future increases in federal investment in education and training might yield a high rate of return, they are not sufficient to support that conclusion, for three reasons. First, the aggregate estimates neither address net returns because they do not link the historical gains in productivity to specific investments, nor do they compare those gains to the opportunity costs of producing them, which include the cost of students' time as well as the resources used in teaching. Second, the studies estimate total productivity gains obtained in the past, not those to be expected from additional increases in educational attainment in the future. Finally, the aggregate estimates reflect the impact of all investments in education and training and do not focus specifically on the types of investments made by the federal government. Accordingly, analysts supplement the top-down estimates with evidence from bottom-up studies of federal programs.

Bottom-Up Evidence

Federal investments in education and training can be divided into four categories: early childhood, elementary and secondary, postsecondary, and job-related. For some of those investments, little evidence of the economic impact exists. For example, although job-related training (federal and nonfederal) is usually evaluated in terms of its direct effect on employment and earnings, investment in prekindergarten education typically is not. Indeed, the effect on the economy of the latter investment may be of less importance if the primary goal is to equalize educational opportunity. Consequently, the following reviews of the effects of some of the largest federal education programs focus primarily on the programs' direct benefits (growth in achievement, for example), which are a necessary—though not sufficient—condition for them to pass a benefit-cost test of efficiency.

The Head Start Preschool Program. The Head Start program provides comprehensive early childhood developmental, educational, health, nutritional, social, and other services to poor children and their families and is the principal federal program in preschool education. For 1998, the Congress appropriated about $4.4 billion for Head Start, and the Department of Health and Human Services estimated that more than 800,000 children would be served. Among eligible children, Head Start enrolled 41 percent of 4-year-olds, 18 percent of 3-year-olds, and 1 percent of children under 3 in 1996. Since 1989, enrollment in the program has almost doubled and expenditure per enrollee has increased by 50 percent in real terms.

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inferred from the substitution of workers who are paid more for those who are paid less.

Although Head Start centers have operated since the mid-1960s and have received considerable federal support, only limited evidence of their impact exists.[37] The available studies provide some evidence that Head Start produces short-term gains but little evidence of any long-term benefits. In the short term, the program yields higher immunization rates, better nutrition, improved school performance, and reduced rates of grade retention and placement in special education programs.[38] Because repeating a grade generally increases the likelihood of dropping out of school, Head Start may also increase high school graduation rates. Nonetheless, several studies in the 1980s and early 1990s found that the gains in test scores and other achievement measures fade substantially or vanish completely by the end of third or fourth grade.[39]

Can the cost of the program be justified in terms of its economic benefits alone? Perhaps the best evidence on the effectiveness of programs like Head Start comes from long-term evaluations of the Perry Preschool Project, a 1960s-era model program in Ypsilanti, Michigan, operated by teachers trained in early childhood development. An evaluation of the program that followed participants into adulthood found economic benefits—increased employment and earnings, reduced involvement in criminal behavior, and less teenage pregnancy—totaling $5.70 for each dollar invested.[40] Two-thirds of that return came in the form of reduced criminal behavior of participants. Although the services provided by the Perry Preschool were similar to those provided by Head Start, the Perry Preschool employed teachers with more training in early childhood education and also provided tutoring in the home each week, so parents could learn to tutor their own children.

Proponents of Head Start want to expand the program to serve more children and improve the quality and level of services provided, but neither the extent to which enrollment could be increased nor the cost of improving those services is known. Some parents do not enroll their children in Head Start because they prefer other child care arrangements or have little interest in the program.[41] Others may not enroll their children because they work full time and would find it difficult to accommodate Head Start's half-day schedule and requirement of parental

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37. General Accounting Office, *Head Start: Research Provides Little Information on Impact of Current Programs*, HEHS-97-59 (April 1997).

38. Janet Currie and Duncan Thomas, "Does Head Start Make a Difference?" *American Economic Review* (June 1995), pp. 341-363.

39. Those gains fade more quickly for some groups than for others, and there is some evidence that the quality of schooling after Head Start may account for the differences. See Valerie E. Lee and Susanna Loeb, "Where Do Head Start Attendees End Up? One Reason Why Preschool Effects Fade Out," *Educational Evaluation and Policy Analysis*, vol. 17, no. 1 (Spring 1995), pp. 62-82.

40. L. Schweinhart, H. Barnes, and D. Weikart, *Significant Benefits: The High/Scope Perry Preschool Study Through Age 27* (Ypsilanti, Mich.: High/Scope Press, 1993).

41. Even if those parents could be induced to enroll their children in Head Start, their low level of interest in the program would tend to reduce the program's effectiveness for their children.

participation. Expanding the program to a full day to include those children might be worthwhile but would certainly increase costs substantially. Some Head Start centers are taking another approach, linking up with day care or child care providers so that a child can have continuous care without a significant increase in the cost of the Head Start component.

Head Start supporters are concerned about the high rate of teacher turnover and the many teachers who are not trained in early childhood development. Some observers advocate increasing teachers' salaries to encourage retention and to support a requirement that teachers be trained in early childhood education. Doing so would be expensive, however, and its effectiveness in reducing turnover or increasing quality is untested.

Title I Support for K-12 Education of the Disadvantaged. Title I of the Elementary and Secondary Education Act, designed to improve educational opportunities for disadvantaged children in schools with a high proportion of poor children, is the largest single federal investment in K-12 education, with a 1998 appropriation above $7 billion. In recent years, Title I has reached more than six million children annually, primarily in the early elementary grades. Typically, Title I supports supplementary instruction in reading and math; close to half of all low-achieving students in the early grades now receive some form of compensatory education assistance in reading or language arts. Participation levels in the upper grades are considerably lower, with less than one-fourth of low-achieving eighth graders receiving reading assistance.

A recent review of 17 major federal evaluations of Title I concluded that the program produces a modest overall impact.[42] In particular, the review found that Title I services improve the standing of disadvantaged students by an average of 2.3 percentage points, a small fraction of the gap between Title I students and their more economically and educationally advantaged peers. One reason for the relatively low level of success is that many students regress during the summer, with math scores and scores of high school students showing the largest losses. On a more positive note, the review found evidence that the effectiveness of Title I services has grown over time, possibly as a result of expanded federal oversight and greater focus on program improvement.

The most recent evaluation of Title I, called the Prospects Study, employs a better evaluation design than most previous studies. It follows a sample of first, third, and seventh graders for six years, testing them in reading and mathematics. The sample includes both students who receive Title I services and those who do not. Observations during the first year of the study generally showed that the achievement of students receiving compensatory educational services did not improve relative to

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42. Geoffrey D. Borman and Jerome V. D'Agostino, "Title I and Student Achievement: A Meta-Analysis of Federal Evaluation Results," *Educational Evaluation and Policy Analysis,* vol. 18, no. 4 (Winter 1996), pp. 309-329.

their peers. In particular, the ranking of Title I participants improved only for seventh graders in reading, whereas it dropped for third graders both in reading and math and for seventh graders in math.[43]

In short, the evidence available so far indicates that current Title I services at best have a marginal impact on the educational achievement of disadvantaged children. Although there may be other reasons for providing those services, there is no reason to think that expanding them would have a positive impact on economic growth.

Financial Aid for Postsecondary Students. Analysts believe that one source of economic growth in the decades since World War II has been the sharp increase in participation in postsecondary education. Compared with high school graduates, workers who hold four-year and professional degrees earn 55 percent and 90 percent more, respectively, which suggests that additional investment in postsecondary education could be profitable. Students have apparently drawn the same conclusion: despite the near doubling of tuition and fees between 1980 and 1995, the proportion of high school graduates enrolling in college continued its postwar increase during that period, rising another 25 percent.[44]

Given the already high rate of participation in postsecondary education, however, efforts to push that rate even higher may not be cost-effective. The United States ranks highest in entry into higher education among the countries of the Organization for Economic Cooperation and Development.[45] In October 1995, 62 percent of that year's high school graduates had enrolled in college—22 percent in two-year colleges and 40 percent in four-year colleges.[46] More would enroll after some delay; 72 percent of the high school class of 1992 had enrolled in postsecondary education by 1994.[47]

Low-cost public institutions and federal financial aid—grants, loans, and work-study—have helped raise college enrollment rates. Although average tuition and fees at public four-year colleges rose in inflation-adjusted terms from $1,300 in

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43. Abt Associates, *Prospects: The Congressionally Mandated Study of Educational Growth and Opportunity: Analysis and Highlights,* prepared for the Department of Education, Office of the Under Secretary, Planning and Evaluation Service, 1995 (available at http://www.ed.gov/offices/OUS/eval/esed/prospect.html).

44. Department of Education, National Center for Education Statistics, *The Condition of Education 1977,* NCES 97-388 (prepared by Thomas M. Smith and others, June 1997), p. 62, and *The Condition of Education 1997, Supplemental and Standard Error Tables*, NCES 97-988 (June 1997), p. 52.

45. Organization for Economic Cooperation and Development, *Education at a Glance: OECD Indicators, 1997* (Paris: Centre for Educational Research and Innovation, 1997), pp. 160, 167. The United States was first in "net entry rate into university-level education," first in female participation in "tertiary education," and third in male participation.

46. Department of Education, *The Condition of Education 1997*, p. 62.

47. Ibid., p. 64.

1980 to $2,600 in 1995, those costs are still well below the colleges' average expenditure per student of $13,000. The difference is funded primarily by state appropriations. Moreover, during the 1995-1996 academic year, a total of $27 billion in federal student aid was granted nationwide to almost 40 percent of the 16.7 million undergraduate students at an average of about $4,500 per recipient.[48] The percentage of students receiving aid varied by family income and the type of institution attended. For example, 63 percent of dependent students (usually under age 24) from families with income below $20,000 received federal aid, as did 71 percent of students attending for-profit schools (usually vocational-technical programs).

Proposals to promote economic growth by further raising participation and investment in postsecondary education face two challenges. First, they would need to be cost-effective in increasing enrollment above its current high level. Although evidence suggests that financial aid—whether targeted toward low-income students, as in the Pell grant program, or broadly available, as with the recently enacted tuition tax credits—may increase enrollment rates, its cost-effectiveness is less clear. One review of the literature on targeted grant aid estimated that between 1 million and 1.3 million full-time postsecondary students in the 1982-1983 school year would not have enrolled without it: that includes roughly 32 percent of low-income students and 13 percent of middle-income students.[49] New studies need to examine more recent experience with such aid in light of the sharp rise in enrollment rates since 1980. Recent evidence shows that enrollment is responsive to tuition rates, particularly at two-year colleges; thus, tax credits could succeed in raising enrollment if they are widely known and perceived as a tuition rebate.[50] Because the credits are not targeted, however, a large number of students who would have enrolled in any case will also use the credits, increasing the federal cost. The benefits of the credits will be shared between students and educational institutions, which are likely to raise tuition in light of students' increased "buying power."

Second, even if additional federal spending did have a significant impact on enrollment rates, it might not produce commensurate gains in education and workforce productivity. High school graduates who are "on the margin" regarding the decision to pursue additional education are much more likely to attend a two-year

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48. Department of Education, National Center for Education Statistics, *National Postsecondary Student Aid Study: Student Financial Aid Estimates for 1995-96*, NCES 97-570 (August 1997). In addition, tax credits are now available. The HOPE tuition tax credit of up to $1,500 per year is available to most first- and second-year students attending half time or more. The Lifetime Learning credit effectively reduces tuition by 20 percent on the first $5,000 for most other students.

49. See Larry L. Leslie and Paul T. Brinkman, *The Economic Value of Higher Education*, 2nd ed. (Phoenix, Ariz.: American Council on Education and Orynx Press, 1993), p. 156.

50. One study, for example, finds that the gap in enrollment between high- and low-income youth has recently grown the most in those states with the largest tuition increases; the study estimates that a $1,000 difference in public two-year tuition is associated with a 19 percent to 29 percent difference in enrollment rates of 18- to 19-year-olds. Thomas K. Kane, "Rising Public College Tuition and College Entry: How Well Do Public Subsidies Promote Access to College?" Working Paper No. 5164 (Cambridge, Mass.: National Bureau for Economic Research, July 1995).

college or vocational-technical institute than a four-year school. But the evidence of positive returns to completing a two-year program is less solid than that for a bachelor's or first professional degree, possibly because the skills developed in the shorter programs do not always match what employers need and are willing to reward.[51] Students who could be induced to choose a four-year program by additional federal aid would probably be less well prepared, on average, than current students. Institutions of higher education are already providing a great deal of remedial education to students and finding that those students are less likely to complete their degrees.

Job Training. The training efforts of the federal government have a different focus than those of private employers. Private employers tend to spend their training dollars on employees who have demonstrated an ability to learn (for example, by holding a college degree) and an interest in the job and the company. In contrast, the federal government currently focuses on the disadvantaged, particularly workers without a high school degree, and "dislocated" workers, whose existing skills have fallen in value because of changes in technology or market conditions.[52]

Job training for the disadvantaged falls into two categories: voluntary programs for adults and youth and mandatory programs for welfare recipients. The Job Training Partnership Act (JTPA), first enacted in 1982, is the primary federal vehicle for voluntary job-related training. JTPA is composed of programs that train economically disadvantaged individuals facing serious barriers to employment; appropriations for JTPA in 1998 totaled $5.0 billion.

From 1991 until its repeal in 1996, the Job Opportunities and Basic Skills (JOBS) program governed training for welfare recipients. In contrast to earlier federal efforts, JOBS required participation of most AFDC (Aid to Families with Dependent Children) mothers with children age 3 and older and stressed education, including postsecondary education. The new Temporary Assistance for Needy Families (TANF) program has a "work activities" requirement that generally excludes education from the menu of acceptable activities. There is an exception for dropouts, but starting in 1998 that exception excludes vocational education.

Many studies have analyzed the effectiveness of government training programs for the economically disadvantaged. In a recent review of the evidence, Daniel Friedlander, David Greenberg, and Philip Robins conclude:

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51. See Thomas J. Kane and Cecilia Elena Rouse, "Labor-Market Returns to Two- and Four-Year College," *American Economic Review*, vol. 85, no. 3 (June 1995), pp. 601-614; and W. Norton Grubb, "Postsecondary Education and the Sub-Baccalaureate Labor Market: Corrections and Extensions," *Economics of Education Review*, vol. 14, no. 3 (June 1997), pp. 285-299.

52. The federal government also participates in high-skill training through grants to university faculty and teaching hospitals that support the training of college seniors, graduate students, and medical interns.

> The broadest generalization about the current knowledge of government training programs for the disadvantaged is that they have produced modest positive effects on employment and earnings for adult men and women that are roughly commensurate with the modest amounts of resources expended on them. The positive effects for adults are not large enough to produce major aggregate effects on employment and earnings among low-income target groups, and the programs have not made substantial inroads in reducing poverty, income inequality, or welfare use. Moreover, they have failed to produce positive effects for youth.[53]

Even the modest level of effectiveness of JTPA programs observed in some groups might not hold if the programs were expanded significantly. Although the evaluations of JTPA programs have become quite sophisticated, the evidence about what services work and for whom is still inconclusive.[54] Consequently, the literature does not yield clear guidance as to whether further efforts to assist the disadvantaged in improving their opportunities in the labor market should focus on classroom training, on-the-job training combined with job search assistance, or other services.[55] In the case of disadvantaged youth, a variety of approaches have been attempted, and only Job Corps, a residential program that is costly and inappropriate for most, has shown any promising results.

Current federal efforts to assist displaced workers include classroom-based academic and occupational training designed to give them skills to make them employable in a new industry or occupation. The evidence from the evaluation literature finds that the rate of return to such training is very low, sometimes even negative.[56] Other services, such as job-search assistance and reemployment bonuses, cost much less and produce results in employment and earnings that are comparable with those from retraining. Investment in those services has a high rate of return. Such services, however, have limited applicability. They are effective with some displaced workers and some disadvantaged adult women, but less effective with disadvantaged adult men and completely ineffective with disadvantaged youth. In contrast, studies of on-the-job training provided by private employers show that it almost always has a positive return and is often quite profitable. One survey of the

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53. Daniel Friedlander, David H. Greenberg, and Philip K. Robins, "Evaluating Government Training Programs for the Economically Disadvantaged," *Journal of Economic Literature*, vol. 35 (December 1997), p. 1810.

54. Howard S. Bloom and others, "The Benefits and Costs of JTPA Title II-A Programs: Key Findings from the National Job Training Partnership Act Study," *Journal of Human Resources* (Summer 1997), p. 574.

55. Friedlander, Greenberg, and Robins, "Evaluating Government Training Programs," pp. 1847-1848.

56. Yolanda K. Kodrzycki, "Training Programs for Displaced Workers: What Do They Accomplish?" *New England Economic Review* (May-June 1997), p. 44.

evidence concluded that the wage effect of within-company job training is between 4 percent and 16 percent.[57]

Several factors contribute to the lower estimates for publicly sponsored job training. First, public job training is for the unemployed; thus, the skills taught may not match the skills valued by an individual's eventual employer, and the trainees may be less motivated because the training is not tangibly related to a current job. Second, public job training is often for those who have lived in poverty for many years and who have little formal education. Some trainees do not have the literacy skills needed to absorb new material quickly and efficiently. The objective of public job training is to reduce disparities in the distribution of income: increasing the overall productivity of workers is, at best, secondary.

Summary. Although overall investments in education and training contributed substantially to past increases in the productivity of the U.S. workforce, and hence to economic growth, it is not clear that increases in spending on those activities by the federal government would lead to additional growth. Many of the federal education and training initiatives target social goals, such as educational opportunity, rather than workforce productivity. Programs that focus more on economic gains have met with only limited success, and expanding them would offer little assurance of positive economic returns.

FEDERAL INVESTMENTS IN RESEARCH AND DEVELOPMENT

The last three decades have seen major changes in the pattern of U.S. investment in research and development. Although the share of the economy devoted to R&D has remained roughly constant, the balance of funding—and hence decisionmaking authority—has shifted from the federal government to private industry (see Figure 4, above). That shift occurred as the Cold War ended, federal budget pressures rose, and the rapid growth of high-technology industries (semiconductors, personal computers, biotechnology, and so on) provided strong incentives for private investment in R&D. Private funding is now important even in basic research, traditionally an area in which the federal government had a near monopoly. In short, total R&D investment is increasing along with the economy as a whole, but most of that increase is occurring outside the government. Accordingly, this section examines federal R&D investment as an important but not dominant part of the national R&D picture.

57. Wim Groot, Joop Hartog, and Hessel Oosterbeek, "Returns to Within-Company Schooling of Employees: The Case of the Netherlands," in Lisa M. Lynch, ed., *Training and the Private Sector: International Comparisons* (Chicago: University of Chicago Press, 1994).

Trends in Funding for R&D

The United States funds more R&D than any other country. In 1996, the national investment in R&D totaled $193 billion, or 2.6 percent of GDP. The portion of GDP devoted to R&D in 1996 was roughly the same as in 1960, real spending having more than doubled over the period. Yet during that time, federal R&D spending fell from 1.7 percent of GDP (a level driven by spending on defense and space programs in the wake of Sputnik's launch) to 0.8 percent; nonfederal spending rose from 0.9 percent to 1.7 percent.

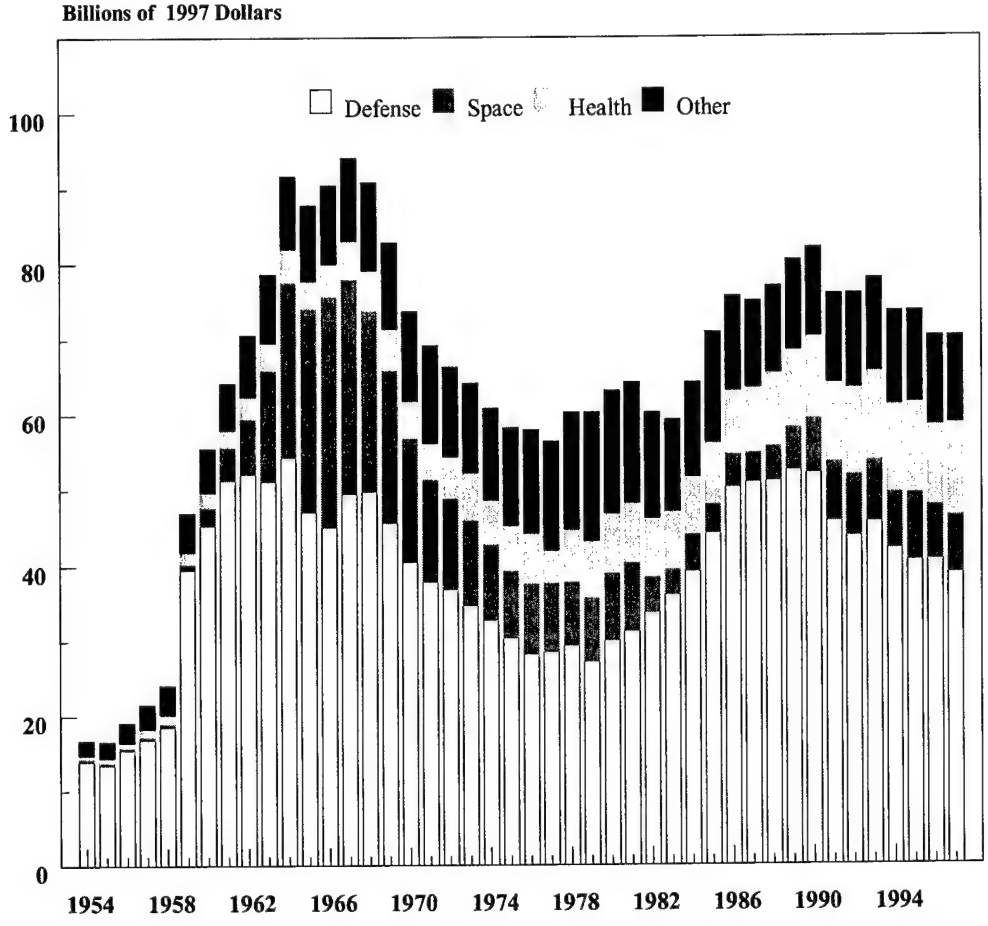
The dominant role now played by industry affects the focus and type of R&D done in the United States. The most recent data suggest dramatic growth in R&D in nonmanufacturing sectors (for example, computer software, communications, and other firms), which now account for over 25 percent of the R&D both financed and performed by industry. Other areas of concentration include motor vehicles, electrical equipment, and pharmaceuticals. Although industry spends a small fraction of its R&D budget on basic research, its share of total national funding for basic research has risen to roughly 25 percent.

Most federal support for R&D goes to defense, space, and health, which together accounted for 83 percent of the $71 billion appropriated for R&D in 1996 (see Figure 6). At $38 billion, defense alone captured over half of federal R&D funding. Another 7 percent ($5 billion) supported basic research in other fields, such as high-energy physics, chemistry, and environmental science. The remaining 10 percent ($8 billion) funded applied R&D related to a variety of federal missions, including natural resources and the environment, energy, aeronautics, agriculture, and commerce. One corollary of the predominant share of defense and space in the federal R&D budget is that most of that spending supports development rather than basic research and is targeted toward the unique missions of the federal government rather than products or processes with broad commercial appeal.

The amount that the federal government spends on basic research, though only 20 percent of all federal R&D, is nonetheless important. It currently accounts for 57 percent of all basic research performed in the country, and about 70 percent of that performed outside industry. Nearly half of federal support for basic research comes from the National Institutes of Health (NIH)—$6.4 billion out of $14 billion in 1996—followed by the National Science Foundation (NSF), the Department of Energy (DOE), and the National Aeronautics and Space Administration (NASA), each spending about $2 billion in 1996, or 14 percent of the total. Smaller budgets in the Department of Defense (DoD) and Department of Agriculture support basic research in engineering and agricultural sciences, respectively.

The government's support for basic and applied research is particularly important to academia, which now relies on the federal government for about 60 percent of its total R&D funding—$13 billion out of $22 billion in 1995. At nearly

FIGURE 6. FEDERAL OUTLAYS FOR RESEARCH AND DEVELOPMENT BY FUNCTION, 1954-1997

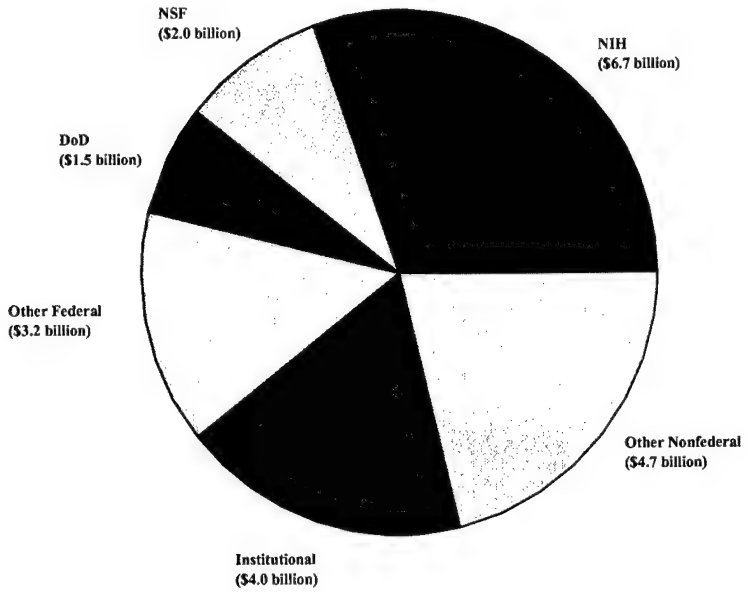


SOURCE: Congressional Budget Office.

$7 billion, NIH was the largest single source of funds for academic R&D, followed by the universities' own internally generated funds ($4 billion) and NSF ($2 billion). Four other sources—state and local governments, industry, nonprofits, and DoD—each contributed about $1.6 billion, and other federal agencies funded a total of $3.2 billion (see Figure 7).

Life sciences researchers receive the largest share of the federal money for academic R&D and also have better access to funds from nonfederal sources (Figure 8). In proportional terms, the academic researchers most heavily dependent on government support are those in the physical sciences (funded largely by NSF, DOE, and NASA) and in math and computer sciences (funded largely by DoD and NSF).

FIGURE 7. SOURCES OF FUNDING FOR ACADEMIC RESEARCH AND DEVELOPMENT, 1995



SOURCE: Congressional Budget Office based on data from the National Science Foundation and the American Association for the Advancement of Science.

NOTE: NIH = National Institutes of Health; DoD = Department of Defense; NSF = National Science Foundation.

Economic Analyses of the Return to Research and Development

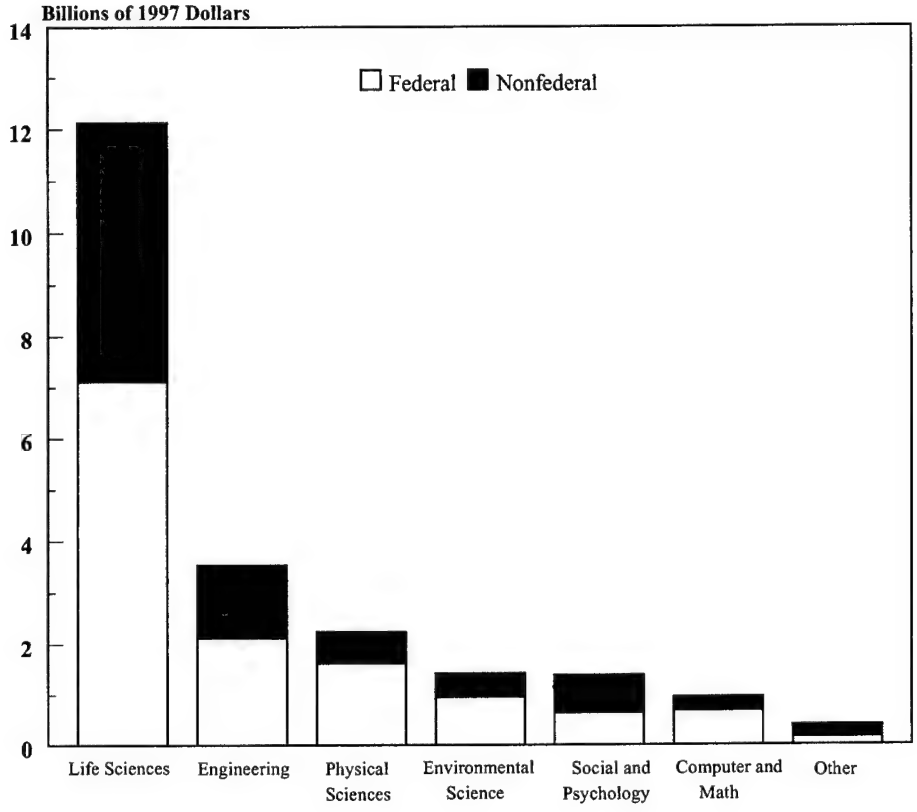
Analysts have used both bottom-up benefit-cost case studies and top-down statistical studies to investigate the contribution of federal R&D to the economy.[58] Generally, the case studies have found that federal R&D spending contributes to the economy substantially in excess of its costs, but the aggregate statistical studies report that federal R&D does not enhance productivity substantially, if at all. That difference occurs because of focus and methodology.

Aggregate Productivity Studies. Economists who measure the return to total national investment in R&D generally find high returns.[59] A review of the literature by Zvi

58. For an earlier review of such studies, see Congressional Budget Office, *How Federal Spending for Public Investments Affects the Economy*, pp. 89-101.

59. Zvi Griliches, "The Search for R&D Spillovers," *Scandinavian Journal of Economics*, vol. 94, Supplement (1992), pp. S29-S47. For a recent review of that literature, see Steven W. Popper, "Economic Approaches to Measuring the Performance and Benefits of Fundamental Science" (Santa Monica, Calif.: RAND Corporation, October 1995).

FIGURE 8. SOURCES OF FUNDING FOR ACADEMIC RESEARCH AND DEVELOPMENT BY DISCIPLINE



SOURCE: Congressional Budget Office based on data from the National Science Foundation.

Griliches suggests that R&D provides society with a rate of return averaging roughly 50 percent, once all the spillover and interindustry effects are accounted for.[60]

With some exceptions, however, studies that distinguish publicly and privately financed R&D find that although the returns to private R&D are high, those to federal R&D are low to nonexistent. That is especially true of the research that the federal government pays industry to conduct, such as that for new weapon systems.[61]

60. The bulk of the individual estimates ranged from 30 percent to 80 percent. Griliches, "The Search for R&D Spillovers," p. S43. For a similar analysis, see M. Ishaq Nadiri, "Innovations and Technological Spillovers," Working Paper No. 4423 (Cambridge, Mass.: National Bureau of Economic Research, August 1993).

61. Some analysts argue that federal R&D programs have negative spillover effects—increasing private R&D costs by bidding up wages of engineers and scientists and luring them away from private endeavors. For discussion of that issue, see Eric Bartelsman, "Federally Sponsored R&D and Productivity Growth," Finance and Economics

The most significant exceptions to the general finding of low returns to federal R&D are academic research (discussed below) and agricultural research, which makes a substantial contribution to productivity growth in agriculture.[62] Yet even in those categories, the net gain to the economy may be overstated to the extent that federal R&D merely substitutes for private funding of the same or similar projects.

The possibility that federal R&D might have low returns is not hard to explain, given that most of it is mission-oriented—that is, related to military, health, or other federal purposes not traditionally measured in terms of economic return. For example, research that increases the capability of weapons might increase the strength of the U.S. armed forces, but official economic indicators cannot measure the added benefit. Since defense R&D alone accounts for roughly half of federal R&D, it exerts a substantial downward bias to measured returns. Similarly, the output of federal R&D in the health sciences is inadequately captured by GDP statistics, which reflect the value of good health only partially and indirectly.[63] By contrast, it is much easier to capture the contribution of R&D to the productivity of manufacturing industries serving consumers in the marketplace.

Moreover, analysts have a hard time observing whatever contribution to productivity federal R&D truly makes. One reason for that is that the federal government invests more in new discoveries, while the private sector concentrates more on improving existing products and processes. Since economic data inadequately measure benefits flowing from new products, they understate the returns to federal R&D. Further, federal R&D spending emphasizes basic research, and if such research yields basic insights, on which private-sector investigators can build to develop commercial products, standard economic statistics may attribute the resulting benefits to the private research, failing to reveal the key complementary role of federal R&D.

Students of R&D policy have produced some evidence that federally sponsored science, particularly that conducted in academia, does indeed play a "bird

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Discussion Series Paper No.121 (Federal Reserve Board, April 1990); and Theofanis Mamuneas and M. Ishaq Nadiri, "Public R&D Policies and Cost Behavior of the U.S. Manufacturing Industries," Working Paper No. 5059 (Cambridge, Mass.: National Bureau of Economic Research, March 1995).

62. A 1996 report by the General Accounting Office (GAO) noted that the flexibility of federal research in agriculture is constrained by past investments in facilities and scientific expertise, Congressional directives, and pressures from various interest groups. Such constraints may tend to reduce the returns to the agricultural research. Nonetheless, GAO's survey of 218 food- and agriculture-related associations found that two-thirds rated research by the federal Agricultural Research Service as somewhat or very effective in meeting their needs, and 80 percent gave those ratings to research conducted at land grant universities, funded in part by federal formulas and grants. General Accounting Office, *Agricultural Research: Information on Research System and USDA's Priority Setting*, GAO/RCED-96-92 (March 1996).

63. Popper, "Economic Approaches to Measuring the Performance and Benefits of Fundamental Science," p. 6. For example, R&D that increased the expected life span from 75 to 80 would clearly be of benefit to society, yet such benefits would be measured only indirectly, by the increase in economic activity resulting from the extra years of life.

dog" role in the economy. A survey of 76 large companies that perform R&D indicated that about 10 percent of their processes and products could not have been developed (without substantial delay) in the absence of recent academic research.[64] Further surveys indicated that almost two-thirds of that research was funded by federal agencies, as opposed to slightly more than one-fifth paid for by industry.

CHI Research, a patent-citation consultancy, has collected indirect evidence on that point.[65] Patent applications include two types of citations: to other patents and to scientific literature. Of the scientific papers cited in patents, 73 percent were articles written by academic scientists or scientists at governmental or other institutions developing what the authors call "public science." The authors argue that industry has increased its reliance on public science over the last decade and that public science is, to a large extent, the product of federal funds.

Benefit-Cost Studies. In contrast, benefit-cost studies of federal R&D projects often find that they make a substantial contribution to the economy. But the narrow focus of such studies makes it difficult to generalize from the reported successes.

An important methodological problem with the benefit-cost approach is that it is biased toward successful projects. The return to the economy from any R&D program is the average of the returns from successful and unsuccessful projects. Studying failures in a systematic way is difficult, however: such projects are often aborted before completion, leaving little record. Accordingly, many analysts argue that benefit-cost studies overstate the average benefits of R&D.

One study that received a great deal of attention was performed by Edwin Mansfield, who tried to compensate for the inherent bias of benefit-cost studies by using conservative assumptions and offsetting known errors.[66] Mansfield estimated that academic R&D gives society a 28 percent return on its investment; given the uncertainties involved, a more appropriate summary of the study is a range from 20 percent to 40 percent.[67] Since most of the funding of those academic researchers

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64. Edwin Mansfield, "Academic Research Underlying Industrial Innovations: Sources, Characteristics, and Financing," *Review of Economics and Statistics* (1995), pp. 55-65.

65. Francis Narin and others, "The Increasing Linkage Between U.S. Technology and Public Science," *Research Policy*, vol. 27 (1997), pp. 317-330.

66. Edwin Mansfield, "Academic Research and Industrial Innovation," *Research Policy*, vol. 20 (February 1991), pp. 1-12. For CBO's analysis of this work, see "A Review of Edwin Mansfield's Estimate of the Rate of Return from Academic Research and Its Relevance to the Federal Budget Process," CBO Staff Memorandum (April 1993).

67. Part of the uncertainty comes from the inevitable difficulty of comparing what actually happened with what would have happened in the absence of the academic research. Mansfield's study surveyed firms in R&D-intensive industries and asked them how long it would have taken them, in the absence of academic research published in the previous 15 years, to bring to market the products and production processes they introduced between 1975 and 1985—a difficult and subjective question.

came from the federal government, the returns should apply, at least roughly, to federal programs that fund academic research.

Mansfield cautioned, however, that he was estimating the average rate of return, not the marginal rate. Thus, the next dollar invested may not provide the same return to society. Indeed, if peer review works as intended, the best research is funded first, ahead of research with weaker prospects. Even though the research most valued by peer reviewers might not have the highest economic rate of return, additional projects funded by increases in federal support for R&D would probably still yield a return near or below the lower end of the estimated range of 20 percent to 40 percent.[68]

Summary. The available literature on federal investment in R&D suggests three conclusions. First, most federal R&D is mission-oriented and typically cannot be justified by its economic return. Instead, it should be judged on its contribution to the federal mission in question (for example, national defense). Second, academic research, such as that supported by the National Science Foundation or the National Institutes of Health, has provided society with a substantial return, and some federal funding for applied research, most notably in agriculture and health, has also more than paid for itself. Third, however, funding increases in those areas may not produce returns as high as those seen at current funding levels. Nevertheless, the economic argument for some level of federal support of academic basic research remains strong.

THE POTENTIAL IMPACT OF INCREASED FEDERAL INVESTMENT

This paper finds that increased federal spending on investment in infrastructure, education and training, and R&D is unlikely to have a perceptible positive effect on economic growth. That conclusion rests in part on the observation that many federal investments have little net economic benefit—either because they are selected for political or other noneconomic reasons or because they displace private-sector or state and local investments. Federal spending can also reduce growth under the following circumstances: when it displaces investment that is more productive; when it leads others to defer investments in the hope of getting federal funds; or when its full costs (including opportunity costs) exceed its benefits. Even federal investments that appear to be economically justified generally have moderate returns, and the supply of those productive investments is limited. Thus, proposals to increase

68. Mansfield found returns that varied widely among research fields; thus, one might hope to reap returns greater than 20 percent by concentrating increases in federal support for academic R&D in fields and types of research with the highest market potential, such as applied research in computer science and pharmaceuticals. However, such fields and projects are precisely those that can most easily find support from private investors and therefore pose the greatest likelihood that additional federal dollars would displace private funds rather than add to total R&D.

federal investment beyond its current level of about $170 billion in 1997, or about 2 percent of GDP, should be evaluated with care.

Based on the available literature on the economic value of federal investments, CBO finds little ground for optimism about the effects of increased federal spending. That literature is incomplete—for example, it pays little attention to the displacement issue—and many studies suffer from methodological flaws. In any event, most of the recent studies on infrastructure investment find modest returns. Analysis by the Federal Highway Administration indicates that some investments in existing roads—particularly resurfacing projects—are productive; in practice, however, federal funds invested in highways and other infrastructure are not always directed to the projects that would be economically efficient. One study's estimate of a 28 percent return to current academic R&D suggests that the government could profitably increase its support of academic research, and perhaps of basic and applied research more generally, but not of development work, which gets the lion's share of funding. The peer review process used to allocate much federal funding for academic research helps insulate such spending from the political pressures that can affect other federal investments. Nonetheless, additional federal dollars might partially substitute for private funds and lower returns can be expected as less-worthy projects become eligible for federal funding. For education and training, some new programs or additional spending on selected programs might yield benefits in terms of increased educational opportunity but would be unlikely to have a measurable effect on economic growth.

In short, the federal government's opportunities for making investments that yield economic benefits are limited. Of course, some do exist: by definition, federal investments that pass a careful benefit-cost test can contribute as much to growth as private investments. And some federal investments that are not justifiable on economic grounds may be desirable for other reasons—for example, if they advance the social goal of equality of educational opportunity. Nonetheless, there is ample reason to be skeptical that increased federal investment spending would increase the growth of GDP.